7.—THE REACTION OF WESTERN AUSTRALIAN SOILS.

L. J. H. TEAKLE and L. W. SAMUEL.

Introductory.

The importance of soil reaction has received emphasis in Australia, particularly in recent years, as a result of the publications and influence of Prescott (1927, 1928) and associates at the Waite Agricultural Research Institute in South Australia. It has been made clear that not only is the knowledge of soil reaction important from the point of view of crop growth, crop selection and manuring, but also as a criterion in soil classification and soil physiology. The effect of climate on rock weathering and soil formation is reflected by the hydrogen ion concentration of the soil suspension, and when regarded from the continental point of view the zonal distribution of soil types shows a very close correlation with climate. Of course many disturbing factors intervene to confuse, but it is always possible to recognise the *normal* soil types of any locality in spite of unconformities.

Prescott (1927) has shown for South Australia the effect of rainfall; other factors being equal, it is generally observed that soils of wetter districts are more acid than soils of dry districts.

The Scope of the Enquiry and Methods adopted.

The soils considered in this paper are all from the Southern part of the State, embracing practically all agricultural areas. The geographic positions of the localities from which samples have been obtained may be seen by reference to the map (Fig. 1). Practically all samples were collected by the senior author to represent typical soil conditions in the several districts, but only certain ones, which will receive special treatment, were sampled on a strict profile basis. In these cases pits were dug and the samples obtained from the walls somewhat similarly to the method of Polynov. The other samples were obtained mainly by the use of a soil auger, and the finer distinctions of the soil horizons not recognised. Nevertheless it is felt that these samples truly represent soil conditions, and the results of their examination are well worth publication in conjunction with the results from the analyses of the type samples more carefully selected.

In presenting the various ideas for consideration and criticism, it is necessary to acknowledge the helpfulness of discussions with Professor J. A. Prescott, of the University of Adelaide, during his extended tour of the country from which the samples were collected. Many of the ideas expressed in this paper have emanated directly from Professor Prescott, and the discussions during the progress of the trip have led to a considerable clarification of the problems of soil classification in Western Australia. Much remains to be done, but it is hoped that these preliminary results will be of assistance to colleagues, particularly in Australia, by affording data concerning the nature and distribution of our major soil types.

The reaction of the soils is expressed in terms of the pH scale. The determinations were made by means of the quinhydrone electrode, following the method of Bijlmann as outlined by Prescott and Piper (1928).

Results.

The soils of the Southern portion of Western Australia present a very confusing picture to the newcomer who attempts to classify the soils according to the zonal system. This is due to the effects of the geological history of this part of the continent resulting in a patchwork and admixture of ancient laterites and the more recently weathered material from basal rocks. The soils now being formed from the laterites, in themselves the remains of previous soils, do not conform to the soil types predicted from a consideration of the present climatic conditions; adjacent soils, whether formed from granites, basic dykes, or sedimentary rocks, may be regarded as "normal," and may be compared with soils formed under similar climatic conditions in other parts of Australia and of the world. Typical podsols are recognised at Albany and along the wetter portions of the coastline: the brown earths range from Cranbrook to Northampton and extend as far East as Bruce Rock and Corrigin. The mallee types, comparable with the mallee types of the Eastern States, extend from the brown earths eastward and northward. There appears to be a considerable overlapping of the brown earth and the mallee types.

Under these circumstances it cannot be expected that the various soil types of Western Australia will all conform to the climatic zones. It will be found, however, if the obvious anomalies are eliminated, if the laterites are treated separately and due allowance is made for admixture, the zonal system of soil classification may well be applied. In the consideration of the results of the soil analyses reported in this paper, an attempt will be made to separate the "normal" soils from the laterites. The separation is extremely difficult in many cases owing to the merging of the two types and to the anomalies resulting from probable admixtures of igneous and lateritic materials.

The records are presented statistically in the form of distribution tables according to the method adopted by Prescott (1927). In designing the tables an effort has been made to bring out the correlation between soil types, rainfall, and soil reaction, when "normal" soils are considered, Table 1, and the lack of correlation when soils of lateritic origin are studied, Table 2.

NAT. MUS. MELB.

TABLE I.—DISTRIBUTION TABLE SHOWING RELATIONSHIP BETWEEN SOIL TYPE, SOIL REACTION AND PRESENT CLIMATIC CONDITIONS WHEN "NORMAL" SOILS ARE CONSIDERED.

Soil Type.	Locality.	Depth.	Rainfall.	Below 3·6	3·6	3·8	4·0	4·2	4·4	4·6	4·8	5·0	5·2	5·4	5·6	5·8	6·0	6·2	6·4	6·6	6·8	7·0	7·2	7·4	7·6	7·8	8·0	8·2	8·4	8·6	8·8	9·0	9·2
?	Ghooli ...	Surface	Inches. 9·44	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...
		0–12in.	(2 yrs.)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Mallee	3,500 Farms Scheme	Surface	10–13*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	2	...	2	3	4	2	2	2	...	...	...	...
		Subsoil	...		...	...	1	...	...	...	...	...	...	1	1	...	...	...	...	...	...	...	...	...	2	3	6	15	7	1	...	...	...
Mallee	Lake Brown	Surface	10·37	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	1	1	1	...	...	...	...	...
		Subsoil	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4	...	...	...
Mallee	Lake King–L. Carmody	Surface	11·94*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	1	6	1	3	...	1	...	...
		Subsoil	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6	5	3	...	...
Mallee	Salmon Gums	Surface	12·75	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	2	1	...	2	1	1	...	...	...	...	...	...
		Subsoil	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	1	...	...	...	1	3	8	3	1	...	...	...	...
Mallee	Merredin ...	1st. ft.,	13·18	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	2	8	10	17	3	...	...
		2nd and 3rd ft.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	9	21	6	...
Mallee	Indarra ...	Surface	13·29†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	2	2	2	1	3	2	2	2	2	2	...	...	...
		Subsoil	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	1	1	1	2	1	3	5	4	7	3	3	3	4	2	...
Mallee	E. Karlgarin	Surface	13·43	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	1	1	1	3	...	1	...	3	1	...	1	...
		Subsoil	(5 yrs.)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	1	...	1	2	3	4	...	...	1
Mallee	Ajana - Dartmoor	Surface	13·90	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	...	...	1	1	2	1	...	...	...	...
		Subsoil	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	2	...	4	1	1	...	...	...
Mallee	Mendel ...	Surface	13·99	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	1	...	...	...	...	...	...	...
		Subsoil	(1 yr.)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	3	...	...	2	...	...	...	...
Mallee	Kondinin ...	Surface	14·00	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	3	...	...	...	...	1	...
		Subsoil	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	1	...	2	1	3	...	...	1
Brown earth ...	Quairading ...	Surface	15·03	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...
		Subsoil	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...
Brown earth and mallee	Corrigin ...	Surface	15·75	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	1	...	...	...	...	...	...	...	...
		Subsoil	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...	1	1	...	1	...	...	...
?	Three Springs	Surface	16·01	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	1	...	...	...	...	...	...	...	...	...	...
		Subsoil	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	1	...	...	...
Basic rock weathering	Ravensthorpe	Surface	16·18	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...
		Subsoil	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...
Brown earth, etc....	Pingelly ...	Surface	17·36	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...	1	...	...	1	...	...	...	...	...	...	...	...	...	...
		Subsoil	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	1	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...
?	York ...	Surface	17·60	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...
		Subsoil	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	1	...	...	...
Brown earth ...	Northampton	Surface	18·21	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	1	...	1	2	...	2	...	...	...	...	...	...	...
		Subsoil	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	1	1	1	3	...	...	...	...	...	...	...	...	...
Leached alkali ...	Moora ...	0–4in.	18·44	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...
		4–8in.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Recent alluvium ...	Greenough ...	Surface	19·61	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	...	1	3	...	...	...	...	...	...	...	...
		Subsoil	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	3	4	3	...	...	...	...	...	...
Rendzina (1) Sands or grits	Gingin ...	Rendzina	31·08	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...
		Sands or grits	...	...	...	...	...	...	...	...	...	...	1	1	...	1	...	...	1	...	...	1	1	...	...	...	...	...	...	...	...	...	...
Alluvial probably...	Busselton ...	Surface	32·04	...	...	...	...	...	...	...	...	...	...	...	3	...	...	2	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		Subsoil	...	...	...	...	...	...	...	...	...	...	...	...	2	...	2	2	2	...	...	2	...	...	...	...	...	...	...	...	...	...	...
Coastal limestone	Spearwood ...	Surface	36·21	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...
		Subsoil	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...	...
Coastal sands ...	Ludlow ...	Surface	...	...	...	...	...	...	...	...	...	...	...	1	1	1	3	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...
		Subsoil	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Coastal marsh ...	Capel ...	Surface	40·30	...	...	...	...	...	1	2	1	1	1	...	2	1	2	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		Subsoil	...	2	...	2	1	2	1	...	2	...	2	1	1	4	...	3	1	...	1	...	...	1	...	...	...	...	...	...	...	...	...
Tobacco	Manjimup ...	Surface	43·46	...	...	...	...	...	...	...	...	...	...	1	...	1	...	1	...	1	...	...	1	...	...	...	...	...	...	...	...	...	...
		Subsoil	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	1	1	1	...	...	...	...	...	...	...	...	...	...	...	...
?	Burekup (Roelands)	0–6in.	45·64	...	...	...	...	...	...	...	2	...	4	1	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		6–12in.	...	...	...	...	...	...	...	...	...	...	1	1	1	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Podsol	Nornalup ...	0–15in.	54·11	...	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		15–36in.	...	...	...	...	...	...	...	...	...	1	...	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

* Records from stations along the No. 1 Rabbit-proof Fence. As these stations were visited but monthly these figures are undoubtedly low.
† Rainfall for Mullewa, 13 miles eastward.

TABLE 2.—DISTRIBUTION TABLE SHOWING LACK OF RELATIONSHIP BETWEEN REACTION OF LATERITIC OR LIGHT LAND SOILS AND PRESENT CLIMATIC CONDITIONS.

pH Value.

Locality.	Depth.	Rain-fall.	Below 3·6.	3·6	3·8	4·0	4·2	4·4	4·6	4·8	5·0	5·2	5·4	5·6	5·8	6·0	6·2	6·4	6·6	6·8	7·0	7·2	7·4	7·6	7·8	8·0	8·2	8·4	8·6	8·8	9·0	9·2
		Inches.																														
Lake Brown ...	Surface	10·37	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	Subsoil	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	**1**	...	...	...	...	...	...	...	...	...	...	...	...
3,500 Farms Scheme	Surface	10·13*	...	...	...	...	...	1	...	...	1	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	Subsoil	...	...	...	...	...	...	**1**	**1**	**2**	...	**1**	**1**	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Ajana - Dartmoor	Surface	13·90	...	...	...	...	...	1	...	...	...	1	...	1	1	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	Subsoil	...	...	...	...	...	...	...	...	**1**	...	...	...	...	**1**	...	**1**	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Mendel ...	Surface	13·99	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...
	Subsoil	(1 yr.)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	**1**	...	...	...	...	...	...	...	...	...	...	...	...	...
Wongan Hills...	Surface	15·36	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Pingelly ...	Surface	17·36	...	...	...	...	...	1	...	...	...	...	...	1	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	Subsoil	...	...	...	...	...	**1**	**1**	**2**	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Esperance ...	Surface	25·74	...	...	...	...	...	...	...	...	1	3	9	3	1	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	Subsoil	...	...	...	...	...	...	...	...	...	**1**	...	...	**1**	**1**	**1**	**2**	**1**	...	**1**	...	...	...	...	...	...	...	...	...	...	...	...

* Records from stations along the No. 1 Rabbit Proof Fence. As these stations were visited but monthly these figures are undoubtedly low.

Having treated the results statistically it seems appropriate to give details concerning certain of the type samples.

Table 3 gives details of the reactions of the profiles of soils of the mallee type.

TABLE 3.—REACTION OF THE LAYERS OF THE PROFILES OF SOILS OF THE MALLEE TYPE.

Merredin. Rainfall 13·18 inches.		Salmon Gums District. Rainfall 12·75 inches.										Fitzgerald Peaks District. Rainfall unknown—Estimated 12 inches.								Lake King. Rainfall—Estimated 12in.	
Sample No. 79.		Sample No. 46.		Sample No. 47.		Sample No. 48.		Sample No. 49.		Sample No. 50.		Sample No. 63.		Sample No. 64.		Sample No.65.		Sample No. 66.		Sample No. 89.	
Depth.	pH.	Depth.	pH.	Depth.	pH.	Depth.	pH.	Depth.	pH.	Depth.	pH.	Depth.	pH.	Depth.	pH.	Depth.	pH.	Depth.	pH.	Depth.	pH.
inches.		inches.		inches.		inches.		inches.		inches.		inches.		inches.		inches.		inches.		inches.	
0—4	6·29	0—3	7·60	0—7	7·05	0—7	7·22	0—6	8·05	0—3	7·02	0—9	7·61	0—3	7·29	0—6	7·86	0—9	7·38	0—4	7·37
4—12	7·19	3—6	7·60	7—15	8·00	8—16	7·94	6—24	8·33	3—10	8·02	9—11	6·19	3—15	8·42	6—27	7·91	9—21	8·16	4—10	8·38
12—18	7·91	6—22	7·86	15—30	8·08	16—36	7·92	24—28	8·21	10—31	8·12	11—21	6·58	15—30	8·45	27—39	8·15	21—30	8·16	10—30	8·54
16—28	8·31	22—42	7·81	30—36	8·05	...	...	...	...	31—48	6·71	...	...	...	...	...	...	...	...	30—48	8·51
28—42	8·38	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Below 48	8·23

Table 4 shows the nature of the profile of a podsol formed under conditions of high rainfall.

TABLE 4.—REACTIONS OF THE LAYERS OF A PODSOL FROM NORNALUP.

Rainfall Average, 54·11 inches per annum.

SAMPLE 78.

Depth.	Soil.	pH.
Inches.		
0– 4	Peaty sand	4·62
4–15	Grey sand and humus	4·50
15–25	Leached coarse grey sand	5·85*
25–30	Incipient humus pan	5·06
30–36	Coarse grey sand	5·35†

* This sample was analysed in quadruplicate owing to the difficulty of getting agreement in the determinations. The readings varied from 220 to 278 millivolts.

† A similar difficulty was experienced, the voltages varying from 188 to 232 millivolts. No explanation can be offered for these irregularities. No " drift " occurred during the reading of the samples.

Table 5 presents the results from certain "anomalous" scrub plain soils South of Lake King.

TABLE 5.—REACTIONS OF HEAVY CLAY SOILS CARRYING LOW SCRUB WITH OR WITHOUT LOW MALLEE, LYING TO THE SOUTH-EAST OF LAKE KING.

The Rainfall is estimated to be about 15 inches per annum.

SAMPLE No. 91.

Depth.	Soil.	pH.
Inches.		
0– 3	Brown loam with quartz and laterite pebbles on surface	7·5
3–12	Pale brown clay	8·5
12–18	Chalky clay	8·5
18–24	Grey clay	8·4

SAMPLE No. 93.

Depth.	Soil.	pH.
Inches.		
0– 5	Brown sand	7·0
5–12	Pale brown clay	8·4
12–22	Brown clay with limestone rubble	8·5
22–25	Tenacious dark brown mottled clay	8·4

SAMPLE No. 94.

Depth.	Soil.	pH.
Inches.		
0– 6	Brown sand	6·9
6–12	Mottled yellow brown clay	6·4
12–18	Yellow clay with limestone rubble on gravel	8·3

Discussion of Results.

1. *The laterites.*—The formation of laterites is receiving considerable attention in Australia at present both from geologists and soil chemists, and it is hoped that, as a result of the thought and discussions on the subject, a clear understanding of them as an agricultural problem will be obtained. It is recognised that Western Australia is most vitally interested, as the occurrence of this geological formation is very much more extensive in the western than in the eastern portion of the continent. It is recognised, too, that the most important and pressing fertility problems in Western Australia are associated with the laterite formations, and their attack and solution depends largely on the understanding of the nature of this type. It is the opinion in certain quarters that laterisation of rock materials is not proceeding at present in the southern portion of Western Australia, it being held that the laterites at present exposed are "fossil" soils, the relics of a pre-historic climate, presumably of high and intermittent rainfall associated with high temperatures. While there is much opinion against this theory it seems highly tenable to many soil chemists and is being used as a very useful "hypothesis" at present.

Strong support for this hypothesis is afforded by the work of Martin and Doyne in Sierra Leone, West Africa (1927, 1930), where laterite is actually forming *in situ* from basic rocks under the present climatic conditions of 150 to 180 inches of rainfall per annum and tropical temperatures. The significant feature of their findings in connection with the discussion in this paper is the fact that these basic rocks are yielding a soil with a reaction ranging from pH 4.5 to pH 5.5, the surface being the more acid. In Western Australia we find lateritic soils under most climatic conditions and, as far as the investigation has proceeded to date, it is found that these soils are uniformly acid, independent of present climate. It seems reasonable to postulate that this condition of acidity is the impress of another epoch: is the result of soil formation under entirely different climatic conditions from those operating at present. This idea receives very strong support from the fact that contiguous soils, formed directly from granites, basic or sedimentary rocks, show a response to the present climate in the formation of mallee soils, brown earth, or podsols according to the conditions. Laterite soils or lateritic materials are found overlying these same rocks in the same districts. A study of Tables 1 and 2 will reveal the evidence obtained in support of this argument.

2. *The "normal" soils.*—This term is used advisedly and includes those types which fit in with the zonal system of soil classification as suggested by Prescott. The mallee, brown earth, and podsol types are regarded as typically "normal" soils, being formed directly from recognised igneous or sedimentary rocks. The profile and reaction of these soils are distinctly related to the climate. The correlation between reaction and rainfall in particular is well illustrated by distribution Table 1. It is seen that the soils are alkaline under low rainfall conditions and become progressively more acidic with increased rainfall conditions, the extremes being the mallee soils under a 10 to 15 inch annual rainfall and the podsols of the South-West under 40 to 50 inch annual rainfall. Other soils, particularly those from certain districts of the South-West, have been difficult to place, but for convenience are included in this group in the absence of more complete information.

The several types are discussed in some details below.

a.—*The mallee types.*

The term mallee type is here used to include all normal soils formed under a relatively low winter rainfall, ranging from 10 to 15 inches per annum. The soils vary from sands to clays and invariably show an accumulation of calcium carbonate in the subsoil at a depth of from 8 to 20 inches. The calcium carbonate may occur in a chalky form or as small or large nodules of travertine. Occasionally it occurs as a sheet of travertine 8 to 10 inches below the surface. Under certain conditions there may be calcium carbonate even in the surface layers, either in the finely divided form or as nodules.

The vegetation varies from mallee scrub to large timber such as salmon gum (Eucalyptus salmonophloia), gimlet (Euc. salubris), and morrel (Euc. longicornis, Euc. oleosa, and Euc. melanoxylon). The Eastern wheat belt of Western Australia is entirely within the zone of the mallee soil type, and these soils are known to be very productive under favourable rainfall conditions and suitable management.

The reaction of the mallee soils is on the alkaline side with a mean in the neighbourhood of pH 8. The A horizon, often 3 to 4 inches in the heavier textured soils and as deep as 12 or 15 inches in light textured soils, is usually slightly acid, while the subsoil, in this case the B2 horizon, is invariably more alkaline. When a definite C horizon is reached it is sometimes found to be distinctly acid. See Tables 1 and 3.

b.—*The brown earth types.*

These soils are formed under conditions of higher rainfall and are found in districts with rainfalls ranging from 15 inches to about 25 inches. These soils are less alkaline than the mallee type and appear to range in reaction from pH 6.0 to pH 7.5. Exceptions occur, but sufficient evidence has not yet been accumulated to explain them, or to evaluate their significance. To this group belong the best lands of the Great Southern districts, the Northampton and Chapman districts, the Northam, York, and Toodyay districts, and probably part of the Midland districts.

c.—*The soils of the South-West.*

Reference to Table 1 will show that the soils of the South-West are on the acid side. In general they are podsols or podsolised. No complete discussion can be attempted at present as these soils are formed from laterites, igneous rocks, and transported materials, and sufficient study has not yet been made to attempt even a rough classification or separation of the major soil types. It appears that, whether the material concerned is igneous or lateritic, podsolisation or severe leaching is taking place, and soils relatively low in mineral plant foods predominate.

An interesting soil type of the South-Western districts is the marsh or coastal swamp. Marshes appear to occur along the coast Southward from Gingin. They are often but a few feet above sea level, are acid in reaction, and require drainage. A peculiar feature is the intense acidity of the deeper subsoils, reactions as low as pH 2.8 being recorded for subsoils from

Capel. This acidity has been explained by Dr. E. S. Simpson, Government Analyst and Mineralogist, as being due to sulphuric acid formed by the oxidation of marcasite which occurs in the deeper subsoils.

d.—*The solonetz or leached alkali soils.*

Evidences of soils being leached with solutions containing sodium salts are obtained from various parts of the State. Samples were obtained from a casuarina glauca flat at Moora and on analysis it was found that the soil was slightly acid. The surface soil (0-4in.) was a grey sandy loam and the subsoil (4-8in.) a very tough, grey hard pan. Studies on the nature of the replaceable bases of these soils are needed before any discussion can be indulged in.

e.—*The rendzina soils.*

Under certain conditions limestones or chalks weather to form a lime-humus or rendzina soil—a black clay, rich in humus. These soils occur on the Gingin chalks of Gingin and Dandarragan and, probably, near Dongarra. They are pasture soils, treeless in the virgin condition, and are noted for the fattening quality of the feed produced. They are alkaline soils occurring under climatic conditions which are conducive to the formation of soils of an acid reaction.

f.—*"Anomalous" scrub plain soils.*

Soils bearing scrub in the part of Western Australia under consideration are expected to be either sandy or gravelly. Exceptions were found in the area south of Lake King and at Mt. Madden. At these places poor, low scrub was found on relatively heavy clay soils with calcareous subsoils—soils which would be expected to carry mallee or timber. No explanation can at present be offered, but efforts will be made to obtain evidence with a view to ascertaining the controlling factors responsible for the absence of timber. A knowledge of these factors should be of great value in devising the most suitable management for scrub plain soils.

From the details presented and discussed it is hoped that the foundations may be laid for a systematic and scientific study of our soils which present so many interesting economic and scientific problems. It is believed that, as the body of exact information accumulates along these lines, more and more accurate advice will be available for the benefit of the agriculturalist in particular and the country in general. In view of the demand for lower production costs, it seems pertinent to offer the methods of science as an invaluable adjunct to the efforts of the primary producer, being confident that these will be as effective in agricultural practice as in industrial developments.

Summary.

The paper deals with the results of the study of the reaction of a large number of soil samples collected to represent typical soils in the Southern part of Western Australia.

The results are expressed in two distribution tables and three ordinary tables. The geographical positions of the localities sampled are indicated on a map.

The reactions were determined by means of the quinhydrone electrode.

The following conclusions are suggested from a study of the results:—

1. Two classes of soils occur in the area investigated—
   (a.) the lateritic soils now being formed from laterites;
   (b) "normal" soils forming by direct weathering of igneous or sedimentary rocks.

2. The lateritic soils are almost invariably acid in reaction, the reaction showing no correlation with the rainfall or other climatic factor.

3. The laterites have formed under entirely different climatic conditions from those now operating and may be regarded as fossil soils.

4. The "normal" soils show a very close correlation between soil reaction, soil profile, and climate as measured by the rainfall factor.

5. The normal soils studied fall into three main zonal types—
   (a) Mallee—alkaline soils formed under conditions of low rainfall ranging from 10 to 15 inches.
   (b) Brown earths—slightly acid to slightly alkaline soils formed under conditions of higher rainfall, ranging from 14 inches to about 25 inches.
   (c) Podsols forming under conditions of high rainfall, ranging from about 20 inches upwards. These soils are distinctly acid in reaction.

6. A study of the distribution table shows that alkaline soils normally form under conditions of low rainfall and that soils become progressively more acidic in character as the rainfall increases until the highly leached, acidic podsol is obtained under high rainfall conditions.

BIBLIOGRAPHY.

Martin, F. J., and Doyne, H. C.:

1927. Laterite and Lateritic Soils in Sierra Leone I. Jour. Agric. Sci. 17: 530-547.

1930. Laterite and Lateritic Soils in Sierra Leone II. *Ibid.* 20: 135-143.

Prescott, J. A.:

1926. Soil Classification and Survey. Rept. Aust. Assn. Adv. Science 18: 724-728.

1927. The Reaction of South Australian Soils. Trans. Roy. Soc. S. Aust. 51: 287-290.

1928. The Agricultural Significance of Soil Reaction. Rept. Hobart Meeting, 1928, Aust. Assn. Adv. Science 19: 566-574.

Prescott, J. A., and Piper, C. S.:

1928. Methods for the Examination of Soils. C.S.I.R. (Australia) Pamphlet No. 8.

Prescott, J. A.:

1930. A Tentative Soil Map of Australia. Jour. C.S.I.R. (Australia) 3: 123-124.